Toward Transdisciplinary Research
Historical and Contemporary Perspectives

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Abstract: Over the past two decades a variety of national and international efforts has sought to bring together health and social scientists to address complex health issues. This paper reviews how the notion of transdisciplinary research has emerged; discusses research programs that have successfully traversed discipline boundaries in sustained fashion; considers facilitating and constraining factors that have emerged from the analyses of this process; and suggests next steps for conceptualizing, organizing, and assessing transdisciplinary research based on the notion of heterarchy.
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Introduction

Contemporary health and social scientists increasingly endorse research that crosses disciplinary lines. Health scientists often refer to social conditions in their research on disease-specific and system-related problems. Similarly, social scientists working on topics related to health at least give a nod toward epidemiology. Yet 50 years after the publication of Paul's path-breaking book[1] that pointed to the generative results of social scientists reaching out to address health problems, research that consistently and creatively crosses disciplinary, departmental, and faculty lines remains relatively difficult to initiate, fund, publish, and sustain.

In this paper we offer, first, a contribution to understanding the programmatic and scientific context in which the concept of transdisciplinary research linking the health and social sciences emerged as an attempt to move beyond conceptual and institutional inertia. The focus is on Rosenfield's 1992 paper[2] because it has served as an entry point for much of the current discussion of health research across disciplinary boundaries. We then consider ideas resulting from contemporary research programs that, consistent with that initial analysis, have successfully traversed discipline boundaries in sustained fashion and, in some instances, achieved levels of integrative creative collaboration. These considerations suggest the persistence of factors that constrain boundary-crossing inquiry but also findings that point to the rich promise of such integrative inquiry. Finally, we suggest possible next steps that may serve as a catalyst for promoting and guiding the conduct of transdisciplinary research.

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The Concept of Transdisciplinarity: Parallel Developments

World Health Organization

In the late 1970s, Patricia Rosenfield joined the WHO as the economist for the Tropical Disease Research (TDR) program and responsible for its Social and Economic Research (SER) Steering Committee. Even with supportive TDR leadership, she found a situation similar to what George Foster,[3] a pioneer in medical anthropology, later described as a challenge at WHO since its founding. The early (1947) commitment of those "far-sighted medical doctors and international health workers [who] began to realize that the effective delivery of health care, especially in cross-cultural settings, involved sociocultural as well as purely medical factors,"[3] was not being fully honored. For example, the medical staff would usually ask social scientists to provide manuals and develop questionnaires but not to identify the social and behavioral factors that might inform a deeper understanding of communities' health conditions. Foster also observed that the review process for research support at WHO entailed primarily medical doctors evaluating social science proposals. As a result, social scientists were only rarely full-fledged members of the health team.

The SER committee, however, had several advantages that enabled it to overcome the constraints noted by Foster. First, the TDR program was funded as an extra-budgetary program; several donors (notably from Scandinavian countries and the World Bank) insisted that social and economic factors be studied along with biomedical factors in the analysis of disease transmission and control. Also, the SER steering committee was composed primarily of social scientists charged with the

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responsibility of reviewing and funding proposals submitted by teams of social and health scientists, ensuring knowledge of and respect for the social science aspects of proposals. Further, the committee was part of a larger biomedical program with equal standing to all the other committees (e.g., epidemiology, biomedical sciences, and several disease-specific groups). This structure constituted a considerable organizational advantage, providing access to WHO disease-control specialists and the health policy aspects of projects. It also facilitated collaboration with health ministries, national disease-control programs, public health institutes, and medical schools, as well as social science programs and other ministries.

In its early stages, the committee still faced some of the constraints noted by Foster,[3] notably problems of credibility and legitimacy within WHO.[2] Staff malariologists, for example, were convinced that they understood communities better than social scientists because they were in the field spraying mosquitoes after obtaining local permission. Other disease and vector-control specialists felt that adding social scientists to the team would waste time and money. Nevertheless, social scientists in developing countries were willing to engage in research with their counterparts in the health sciences and health ministries. Together they developed and implemented projects that won over many of the skeptics inside WHO, in ministries, and academic social science departments. As a result, interdisciplinary teams tackled such topics as knowledge of disease transmission, attitudes toward disease-control programs, and new methods focused, for example, on household instead of individual units of analysis. These teams produced results that helped communities and intervention programs reshape their approaches to disease control.[2]

Notwithstanding the success of this process, Rosenfield became concerned that cross-disciplinary work was becoming a fad within WHO, rather than a theoretically and methodologically sound approach for research leading to changes in the delivery of health care and disease control. In particular, terms such as *multidisciplinary* were often used without sustained attention to the fundamental question: *How can collaboration across disciplines lead to new ways of framing, understanding, and addressing human health issues?* Her concern was that superficial use, or even misuse, of such terms would lead to recommendations for changes in the design and delivery of health programs that could waste resources, dash raised expectations, and even eliminate the opportunity for effective partnerships between heath and social scientists.

Given this concern, Rosenfield decided to examine the meaning of *multidisciplinary* and *interdisciplinary* research as expressed by her health and biomedical counterparts. Reviewing projects supported by TDR, as well as programs outside of WHO such as the Applied Diarrheal Disease Research Program,[2] she concluded that the problems Foster[3] had identified persisted in the 1990s, and not just at WHO. What was called multidisciplinary or even interdisciplinary research involved primarily separate input of different disciplines, but **not** creative ways to blend those to yield deeper understanding of the problem or integrative solutions that would be both more acceptable to the population at risk and more cost-effective in the long run. This recognition—that terminology was fuzzy, leading to unmet expectations and limited usefulness of results that did not match some of the associated claims[a]—is what prompted her 1992 paper.[2,b] And as clearly conveyed by other papers in this supplement to the *American Journal of Preventive Medicine*, this analysis—both linguistic and conceptual—has helped stimulate a body of work aimed at further clarifying the distinctions between different forms of cross-disciplinary research and underlining the value-added contributions of using a transdisciplinary framework for both the analysis and solution of health problems.

Europe and the U.S.

Paradigmatic change was taking place elsewhere, both prior to and in parallel with the efforts at WHO. As early as 1970, writing about different forms of knowledge, Judge and Clark[5] had used the term *trans-disciplinary*. Through the 1970s and 1980s, several scholars in Europe and some in the U.S.—primarily from the areas of ecology, computers, and complexity analysis—began to consider the meaning and use of the concept of transdisciplinarity.[5,6]

Then, in the early 1990s, with an increasing recognition of complexity associated with globalization, the social science community in Europe began to consider the concept of transdisciplinarity.[7,8] In 1994 the First World Congress of Transdisciplinarity was held in Portugal and a charter of transdisciplinarity endorsed by the participants. Article 14 of the Charter, *inter alia*, is relevant for current discussions in the health field:

> *Rigor*, *openness*, and *tolerance* are the fundamental characteristics of the transdisciplinary attitude and vision. *Rigor* in argument, taking into account all existing data, is the best defense against possible distortions. *Openness* involves an acceptance of the unknown, the unexpected and the unforesee-

[a]On the persistent issue of fuzzy terminology, see our closing paragraph below and reference 4.

[b]It is encouraging to note that the SER work thrives in 2007 as an active part of the TDR Programme, funding research and training projects in the developing world. Moreover, at a recent TDR meeting, the Ghanaian Minister of Health, Major Courage Quashigah, noted the following: "There's nothing more powerful than an idea whose time has come . . . Although this meeting is focusing on health, the outcome is about how effectively we formulate policies that can help reduce the disease burden in developing countries. To do this, health research must increasingly have a social and ethno-cultural outlook." TDR NEWS, Special issue from Africa, October 2006, p. 4.

able. *Tolerance* implies acknowledging the right to ideas and truths opposed to our own.[7,8]

Since then, as Klein[9]—a leading analyst of transdisciplinary research approaches—elucidates, the domain has burgeoned, as signaled by annual prizes to recognize excellence in transdisciplinary research, the establishment of an Institute in Switzerland, a journal, and an increasingly active presence on the web.[10–12] Moreover, the Strategic Plan of the European Science Foundation for the period 2006–2010 mentions not only multidisciplinary and interdisciplinary research, but also refers to transdisciplinary work in the Humanities section, highlighting health and disease as a major theme.[13]

Finally, in 2006 Stokols extended the examination of transdisciplinary approaches to a level that includes attempted links between research and broader action.[14] Pooling multiple approaches from research and action in his comprehensive review, Stokols outlined "programmatic directions for the scientific study of transdisciplinary research and community action . . . to identify strategies for refining and sustaining future collaborations (and their intended outcomes) among researchers, community members and organizations."[14] Along with his other writings, Stokols' work clearly complements the analysis provided here and elsewhere.[15,c]

Extending the Concept: Illustrative Cases Developing Countries

As a further notable development in the 1990s, the concept of transdisciplinary research across the health and social sciences was taking hold in the developing world. Spurred primarily by the innovative work at the University of Newcastle (Australia) under the leadership of Albrecht and Higginbotham, social and health scientists began to produce conceptual analyses and empirical findings in the area of transdisciplinary health research.[16–18] Higginbotham et al.[19] also took up the challenge to institutionalize the concepts underpinning transdisciplinarity and developed the first curriculum based on this approach, a curriculum still in use at Newcastle for programs in ecosystem health.[d]

In 2002 Higginbotham[20] and his colleagues published a book containing interdisciplinary case studies undertaken in 1990s. Each of the sections reviews the state of knowledge and action in a different region—Asia and the Pacific, Africa, and Latin America. Given the importance, if not uniqueness, of these analyses of health and social science collaboration throughout the developing world, they warrant in-depth study. Here, the emphasis is on only a few central points.

Social scientist Ramos-Jimenez[21] notes the wide range of health conditions in the Asia-Pacific region and the substantial number of scientists, nearly 1000, involved in health social science research. Nevertheless, she also underlines the challenges in crossing "rigid disciplinary boundaries," including the need for better training, material and demonstrations of the actual application of interdisciplinary and transdisciplinary research approaches. She points to effective cases of interdisciplinary research on chronic diseases, such as heart disease, and use of services that are helping to increase understanding and support for interdisciplinary research.

In Africa, sociologist Erinosho[22] notes the commitment of social scientists to work on health issues, but also observes that "a gulf between social and biomedical scientists remains because African biomedical scientists only grudgingly accommodate social scientists working within medical school[s] . . ."[22] Yet in some domains, such as work on traditional medicine and HIV/AIDS, there has been increasing collaboration around the issues of culture-bound programs and the use of ethnographic research. However, despite this critical mass of committed individuals in both regions (Africa and Asia–Pacific), familiar challenges abound, most notably in building and sustaining a sense of partnership across the disciplines and with practitioners and health service decision-makers.

In contrast, sociologist Briceno-Leon[23] observes that in Latin America there has been ". . . long felt appreciation of social issues shown by a number of the region's physicians and public health specialists . . . Many stressed in their writings and actions the importance of society, the environment and people's ways of living toward understanding health."[23] Recently, increased opportunities for collaboration of medical and social scientists have emerged at the community and policy level, especially around disease-specific concerns, so that "potential areas of work and encounter [across fields] have multiplied. The relationship between the social sciences and health is very diverse but also characterized by enormous theoretical wealth and reflection."[23]

Only one case study in the Higginbotham volume explicitly uses a transdisciplinary research framework. Applying the framework to assess the rational use of drugs programs in Indonesia, Hadiyono,[24] a clinical psychologist, describes the challenge of health and social scientists working together as equal partners.

[c]Recent initiatives reviewed in the Kessel and Rosenfield preface[15] include programs of the Canadian Institutes for Health Research that are strikingly consistent with Stokols' focus on community-oriented, action research.

[d]It should be noted that some of the Higginbotham et al.[19] initiatives were supported by Rosenfield after she joined Carnegie Corporation in 1987, with the encouragement of David Hamburg (then the Corporation President). But other foundations and agencies joined the effort, notably the Ford Foundation, the Rockefeller Foundation and the Canadian-based International Development and Research Center. Probably because electronic networking was not well developed, this collaboration took place separately from European efforts, as well as from NCI's leadership initiatives in the area of transdisciplinary research on tobacco.

Based on observations as her team moved through stages from multidisciplinary and interdisciplinary to transdisciplinary collaboration, this analysis of the process yields lessons for those committed to achieving a transdisciplinary research program—namely, the importance of team members':

- willingness to commit sufficient time to such collaborative endeavors,
- openness to learning each other's disciplinary languages and jargon,
- capacity to build mutual confidence and trust, including with community members and practitioners, and
- overcoming the challenge of working as equals, with no knowledge or discipline or practice assuming priority.

Consistent with Stokols' writing cited above, Hadiyono concludes by noting that these studies also brought practitioners and community members together as active participants in the process.

Reviewing their illuminating case studies, Johnson and colleagues[25] underline challenges and opportunities encountered by social and health scientists who seek to cross discipline boundaries, suggesting that such factors are at work in both developed and developing countries. These include:

- the difficulties of defining roles for team members—scientists and researchers, community members and health services personnel—to enable complementary learning and blending expertise and skills at different stages of the research and application process;
- the need to avoid defining the problem either in a narrow, reductive way or so broadly that it becomes practically uninterpretable; and
- the need to overcome discipline rigidity and hyperspecialization as barriers to theoretical and methodologic innovation.

Finally, Johnson and colleagues[25] conclude that, despite such challenges, the promise of transdisciplinary research flows from the recognition that "health social science becomes most effective when the group engaged with the problem adopts transdisciplinary thinking. That is, they transcend disciplinary bounds to synthesize knowledge about the problem in the quest to understand it fully as a complex dynamic system."[25]

The U.S. and the United Kingdom

The National Cancer Institute (NCI)'s 2006 Conference on the Science of Team Science that stimulated this article was a turning point in building understanding and acceptance of the need for transdisciplinary research in health. It is not a coincidence that NCI provided sponsorship. There is ample evidence that NIH support for scientific innovations has been indispensable in promoting and sustaining research collaboration across the health and social sciences.

As only one example, the volume edited by Frank Kessel et al.[26] was supported by the NIH Office of Behavioral and Social Science Research (OBSSR); and several of its case studies illustrated creativity in NIH funding mechanisms, notably at the National Institute of Aging (NIA). NIH was not the only important institutional catalyst, however. Around 1980 the MacArthur Foundation began supporting research networks aimed at establishing connections across disparate research areas, disciplines and universities. And several universities, such as Duke, Wisconsin, and the University of California at San Francisco (UCSF) were early leaders in encouraging interdisciplinary or transdisciplinary initiatives (although not explicitly under such rubrics).

In the 5 years since the Kessel et al.[26] collection of case studies was published, the boundary-crossing trend has not only continued, but also become stronger. The revised edition[27] documents, most significantly, that each of the research teams has been able to stay together and even expand around the core of their research efforts, despite occasional changes in leadership and membership.

One reason for such continuity is sustained funding from foundations and government (in the U.S. and UK), as well as from researchers' home universities. A complementary explanation could be that sustained funding comes about because of the intellectual depth the teams are bringing to understanding problems, along with the significance of their findings and solutions in the field. In other words, like the transdisciplinary tobacco-oriented work funded by NCI, such research programs have at least the potential to make a positive difference in academia, health programs, and households.

Two noteworthy examples of this trend are the case studies prepared by Olshansky and Carnes,[28] and Ryff and Singer.[29] Olshansky and Carnes note that "in the demographic and population sciences, NIH promoted the development of interdisciplinary science by soliciting planning centers through the P20 mechanism (research program project grants) as a way to encourage research consortia to develop new interdisciplinary approaches to solving complex important biomedical research problems."[28] Their own area of biodemography has benefited from this support. Olshansky and Carnes also predict that, as a result of NIH acceptance of multiple investigators, there will be fewer "penalties imposed by promotion and tenure committees on individuals who participate in collaborative activities." Their conclusion: "It is change at NIH that ultimately drives the perceptions and generates a support for interdisciplinary collaboration at universities and departments, not the other way around."[28]

Similarly, in their chapter Postcript, Ryff and Singer[29] observe that obstacles to conducting cross-boundary work, especially those relating to funding and peer-review publications, appear to be weakening. As an important example, NIA has awarded their team a sizable grant to study the biological, psychological and social pathways to positive and not-so-positive health. This will entail a follow-up of their earlier MIDUS (Midlife in the U.S.) work, originally with support from the MacArthur Foundation. They note that "the initial study . . . has become a major forum for publishing 'integrative studies' that cross disciplinary lines in an effort to understand age-related variation in health and well-being."[29] The new NIA P01 program support has enabled the addition of a longitudinal survey as well as biomarkers. Concerned about therapy and applications of their findings, Ryff and Singer are also seeking to partner with researchers engaged in interventions, a key prerequisite for ultimately reaching practitioners.

These examples illustrate how the enhanced quality of research conducted by cross-disciplinary teams has resulted in positive decisions by funding agencies, notably NIH. Such increased support, as noted above, increases the likelihood that universities will respond to the incentives of resources and prestige, for example, by recognizing the value of such research through promotion and tenure decisions that celebrate rather than penalize collaboration and resulting, multiple-authored publications.

Complementing these cases, two chapters in the Kessel et al. volume reflect the experiences of a large multi-member team based in one center and reaching out to many others: Marmot[30] in the studies of aging and the social gradient in the UK, and Chesney and Coates[31] in their research on HIV/AIDS in San Francisco (and elsewhere).

Marmot's case[30] involves an extensive study of aging that is "both multidisciplinary and interdisciplinary . . . [It has] major content in economic, health–clinical, biological and health care and its determinants, social participation and cognitive psychology"[30] and involves scientists from several relevant disciplines. (Marmot himself is an epidemiologist.) The multidisciplinary aspect of the initial study entailed "each discipline working on its own area." But now Marmot reports "a flourishing interdisciplinary environment. For example . . . there's the usual debate as to whether health leads to socioeconomic position or socioeconomic circumstances lead to health. Collaboration between biological sciences and economists show that both are true."[30,e]

Marmot reports that recognition of the significance of such findings **and** the interdisciplinary research process have enabled the center to become formalized as an Institute where members draw on other departments and disciplines in the UK and collaborate with biomedical and social scientists in Latin America, Africa, and Asia. Building on their policy work within the UK, Marmot's team has moved into the global health policy realm through involvement with WHO. Specifically, the Institute serves as host of the Commission on Social Determinants of Health: "The Commissioners, from every region of the world, have expertise in a number of areas apart from health. A major aim . . . is to convince governments and others that planning for health has to involve sectors other than 'health'; and to convince other sectors that [their] policies . . . have vital importance for health."[30]

Updating their chapter on HIV/AIDS prevention, Chesney and Coates[31] describe the changes in the Center for AIDS Prevention Studies (CAPS) since its founding in 1986.[f] They identify the organizational features that have kept the Center functioning productively:

> *Scientific innovation* depends on structure, process and people. The center grant provides the *structure* to stimulate new ideas and organize research projects into coherent programs addressing the full range of HIV/AIDS prevention policy issues. The Center has developed a process that encourages concepts to be developed into innovative research projects . . . and allows us to bring together the *people* . . . The Center is a place for sustenance of scholars devoting their careers to this effort and for the training of new scholars, domestically and internationally, so that the field can respond to future challenges.[31]

The Center for AIDS Prevention Studies now encompasses research across the spectrum of HIV/AIDS–related concerns, for example, oral acquisition of the virus by infants, medication adherence, and household coping mechanisms; HIV-prevention research in minority communities, involving scientists from universities in the U.S. and Puerto Rico; and policy and ethics. It also has strengthened ties to biomedical and clinical investigators at UCSF and to researchers in Africa, Asia, and Latin America. In addition, CAPS had received funding for training in prevention, dissemination of results, and translation of research into practice. Importantly in this context, Chesney and Coates[31] note approvingly the importance of the flexible mechanisms that NIH has now established with regard to the P30 mechanism.

[e]Collaboration between epidemiologists and economists has yielded a comparison of the social gradient in health in English and American white men and women. Since one finding is that the Americans are less healthy than the British, Marmot's research has stimulated much media attention.[32,33]

[f]As the current director of CAPS, Stephen Morin contributed to the chapter Postscript.

Table 1. Factors facilitating and constraining transdisciplinary team science[4]

Factor	Facilitating	Constraining
Focus on major problems	PIs able to bring researchers together across disciplines and program-unifying themes	Some areas seen as unrealistic Lack of integrative research framework Few "how-to" models
Team members (PI et al.)	Possess complementary and intersecting skills Able to develop common language Positive open attitude Appreciative of others' knowledge Shared understanding of scientific problem Mutual trust and respect Open to mentoring others	See skills as competitive Tension between solo and collaborative work Power–prestige differences social and medical sciences Worry about diffusion of focus and loss of identity Research seen as time-consuming/multiple projects Disincentive for practitioners Sharing credit affects promotion, tenure, publications, funding
Training	Complementary training Mentored as grad students to participate in transdisciplinary research team SERCA grants for training in new field	Historical barriers across fields Location of departments Funding limited
Institutions	Support, promote, and fund centers, networks, and teams across disciplines, departments, and medical and social science faculties on same campus	Rigid university policies Centers lacking funds
Technology	Facilitate communication even when teams and researchers physically dispersed	
Funding	Foundations and government support network/team approach (e.g., MacArthur, NIH)	Grant applications more challenging, time-consuming
Publication		Journals discourage multiple authors Peer review hard to judge Need to frame more narrowly

PI, principal investigator; SERCA, Special Emphasis Research Career Award

In our view, the potential for CAPS to become truly transdisciplinary is embedded in all of its projects and successes, even though Chesney and Coates[31] write of themselves as doing "multidisciplinary research." More generally, in a manner similar to tobacco research, the fields of both HIV/AIDS and aging research appear to be promising foci for transdisciplinary attention. Because of their productivity and success, both domestically and internationally, Marmot's Institute and CAPS serve as prototypes that should promote new integrative thinking in these fields.

Issues and Implications from Review of Cases

Drawing on all the case studies in the Rosenfield and Kessel volume, we previously analyzed the factors and circumstances that facilitate and constrain innovation at the boundaries of the health and social sciences.[4,g] Reflecting on the primary theme of the NCI conference, viz., the evaluation of team science, we have revisited that analysis and sketched those factors that appear most salient for transdisciplinary team science in Table 1.

Several of the factors listed in Table 1 also emerged as central themes at the NCI conference. For example, the focus on a complex problem provides the unifying fulcrum for any successful team.[h] Given such a problem focus, team members can understand where their talents can be used and recognize the value of other competencies and perspectives. Further, to achieve such shared understanding, there is a need to establish a common, or at least mutually understood, language. We therefore suggest that along with establishing respect for the contributions of others, perhaps the first step toward building a transdisciplinary team is to develop a common understanding of the dimensions of an energizing problem, whether tobacco-related illnesses, HIV/AIDS, or cardiovascular diseases.

[g]In the course of that commentary, distinctions among multidisciplinary, interdisciplinary, and transdisciplinary research were presented.[4]

[h]"What might be called the-problematic-of-the-problem warrants further analysis since, in scientific practice, what constitutes 'the problem' is often the function or expression of a particular theoretical or disciplinary paradigm. How then do potential collaborators from different disciplines work their way toward a definition of 'the problem' that unites rather than divides them?"[4]

Two crucial elements for achieving such understanding relate closely to the training of team members and the institutional base for the project or program. Researchers who, as graduate students, medical students, or post-doctoral students, acquire understanding about the potential for transdisciplinary research will learn how to respect the value and values of others and to worry less about submerging their professional identity in the team process. And to provide a broad foundation for such a process, the institutional infrastructure of scientific research—universities, journals, and funders—all need to be aligned in support of transdisciplinary team science. Moreover, issues such as promotion, tenure, barriers between departments and faculties, authorship, peer review and grant applications can either support team science or constitute limiting factors. Such findings are reinforced by the 2005 National Academies report,[34] where the table of facilitating factors maps on to Table 1 here and to Rosenfield and Kessel's earlier analyses.[4]

In their overview of the NCI conference papers, Stokols et al. elaborate on these and other concerns, including the importance of evaluating the distinctive nature of the results of transdisciplinary team science where "the scientific, educational and translational aims of TS [team science] are highly diverse."[35] They also refer to the antecedents for successful collaboration, including team members' readiness. Nash,[36] in particular, provides important specificity on the necessary reorientation of training programs and supportive institutional settings, including ways to promote trust, shared competencies, and intellectual risk-taking.

Concern about sustained funding was a consistent theme at the 2006 NCI conference, as was the recognition that NIH support has made possible the innovative transdisciplinary team science reported there. Moreover, such endorsement remains vital for garnering financial and intellectual support from foundations and universities. With this in mind, it is worth highlighting several NIH funding mechanisms that have been noteworthy in facilitating sustained transdisciplinary innovation:

- The NIH Road Map prompts support across individuals and centers;
- P20 Mechanism for research consortia;
- R03 for graduate training;
- NIA support for inter-university teams, randomized control trials, and longitudinal studies; and
- overall NIH recognition and acceptance of multiple, team-based investigators drawn from the full range of medical, health, and social sciences.

What's Missing, What's Needed, What's Next?

Given these conclusions regarding increased recognition of the value of transdisciplinary science and its sustained funding, what's next? One issue raised by several contributors to the NCI conference is the challenge of forging a range of models and methods for team science.[35] More broadly, what ideas might help shape emerging and evolving team explorations of health across diverse disciplinary boundaries in the direction of authentic transdisciplinarity? Complementing the NCI conference papers, Higginbotham et al.[20] pointed to the salience of complexity theory and network theory, and the use of cyber-infrastructure. Similarly, the recent European Science Foundation Strategic Plan calls team science "synergy science" and encourages further exploration of the research process along with ways to reshape discipline structures.[9]

The multiplicity of disciplines, departments, institutions, investigators and sites implied by these views and inherent in the organization of transdisciplinary research as team science has led us to consider what kind of conceptual framework might help shape **and sustain** the evolving exploration of health across all these boundaries. Echoing Foster's decades-old concern,[3] the issue is whether, absent explicit efforts to establish certain characteristics of transdisciplinary team science and even with the best of innovative intentions, a familiar regressive pattern might emerge; that is, where researchers engage in projects involving multiple disciplines that are hierarchically structured. Is there an alternative to such hierarchical structuring?

In the original commentary on case studies of successful interdisciplinary collaboration, inspired by Cacioppo's writings and his research with Berntson,[37] we suggested that the concept of *heterarchy* provides an insightful frame for addressing "human and social problems that are patently complex, multidimensional, and interactive (over time and space)."[4] First introduced in 1945 by McCulloch, one of the pioneers in cognitive science,[38] the concept has been used by paleoanthropologists as they reconsidered the organization of human relations in early human society. Notable among them, Crumley[39] defined heterarchy as the "relation of elements to one another when they are unranked or when they possess the potential for being ranked in a number of different ways."[39] (See also von Goldammer et al.[40])

Several years later the notion of heterarchy is being explored in an increasing variety of areas.[i] Most relevant here, Crumley[48] presents heterarchy as a "robust social theory" because it explicates conditions for selection of an analytical framework that can address the following kinds of questions:

[i]These range from domains close to McCulloch's original scientific interests[41] to areas further afield such as evolution,[42] ecology,[43] and socio-political development,[44] and yet others that circle back to his passion for philosophy[45] and even poetry.[46] The single best sign of McCulloch's intellectual reach comes via the description of his collected papers at the American Philosophical Society.[47]

- How adequate is a model in relating the micro (individual) level to the macro (social) level?
- How adequate is a model in relating the conscious agency of social actors to the social structure in which they operate?
- Can a model provide an explanation for discontinuous and foundational changes in the system as a whole?

Such analyses have convinced us that viewing various facets of the scientific landscape through a heterarchical lens has significant power. In one direction, there are implications for how trans-boundary science is organized and institutionalized, with emphasis on "a network of elements [in this context, disciplines] sharing common goals in which each element shares the same 'horizontal' position of power and authority, each having an equal vote . . . Socially, a heterarchy distributes privilege and decision-making among participants . . . In an organizational context, [heterarchy's] beauty is the way in which it permits the legitimate valuation of multiple skills, types of knowledge or working styles without privileging one over the other."[j] In another, complementary direction, the research of Berntson and Cacioppo,[37] Ryff and Singer,[29] and others demonstrates that understanding the rich complexities of human life (e.g., health processes and outcomes) is most likely to emerge via work that embraces, in theory and research practice, integrative levels of analysis. Berntson and Cacioppo's principles of "multiple, non-additive, and reciprocal determinism" are important corollaries of integrative analysis.[37]

How, then, to conceive of the link between heterarchy and transdisciplinarity? Our propaedeutic proposition—*If transdisciplinarity is the approach for combining-cum-transcending disciplines in integrative, creative, "emergent" ways, heterarchy is both a heuristic metaphor and a potential analytic framework for operationalizing and managing such an approach.*

In less abstract terms, our earlier description of the CAPS foreshadowed a heterarchical frame of that transdisciplinary team. First, the Center's NIH center grant had made it possible to distribute resources for research and training over time and space. Second, changes in leadership have underlined that "rankings" of staff and discipline are constructively fluid. Third, as a central corollary, no discipline or perspective has permanent authorization over any others. As Chesney and Coates[31] point out, the Center has been the hub from which change has emanated—changes in leadership, investigators, research topics, and funding. The overarching focus has been on the process that leads to the most dynamic yet flexible operational style for examining the many levels and dimensions of HIV/AIDS prevention and control, from biomedical to public outreach, from the U.S. to many other countries. CAPS, in other words, is more than a network; it is a heterarchical arrangement of people and projects where processes supporting innovation are paramount.

Our extension of the concept of heterarchy moves it from analysis of complex social systems *per se* to the realm of organizational arrangements that can enhance the capacity to conduct and sustain team science around multi-level, multi-layered health issues located in dynamic social and cultural contexts. Drawing from the field of management science, where heterarchy is used as an analytical concept for research on corporate effectiveness,[50,51,k] and prompted by CAPS and other case studies in Kessel et al.,[27] we propose some initial guidelines for the understanding and assessment of team science capacity:

- establish degrees of flexibility in ranking of leaders, disciplines, and topics in the conduct, sequencing and re-sequencing of research activities[l];
- assess resilience in responding to changing conditions that require re-thinking basic premises (theoretical or methodologic), as well as effectiveness in communicating those changes to different constituencies; and
- assess team effectiveness in bridging multiple contexts within the same geographic site or across sites.

Finally, with such starting guidelines in mind, and given that NIH has developed a series of flexible funding mechanisms to facilitate complex research endeavors, we suggest that a creative next step in the process of conceptualizing and evaluating transdisciplinary team science would be to bring together scientists conducting boundary-crossing research and scholars engaged in elucidating the concept of heterarchy. One primary purpose of such a conversation would be to continue clarifying and sharpening the distinctions—in principle and practice—among multidisciplinary, interdisciplinary, and transdisciplinary research. More broadly, the goal would be to shape reflective substantive and organizational practices on the part of the next generation of transdisciplinary team scientists committed to examining the cultural and social systems in

[j]This quote comes from the *Wikipedia* entry for "heterarchy." Appropriately so, given another part of that entry–"A heterarchical structure processes more information more effectively than hierarchical design. An example of the potential effectiveness of heterarchy would be the rapid growth of the heterarchical Wikipedia project in comparison with the failed growth of the Nupedia project. Heterarchy increasingly trumps hierarchy as complexity and rate of change increase." See also Crumley (2007).[49]

[k]From 1999 to 2001 the Center for Organizational Innovation at Columbia University held a "Heterarchy Seminar". And von Goldammer et al.[40] have applied the concept of heterarchy to decision-making in multiple contexts.

[l]von Goldammer et al.[40] refer to this as "reverse osmosis" of the research process.

which biomedical health conditions are reciprocally and, indeed, heterarchically situated.[m]

Dan Stokols and his colleagues Kara Hall, Rick Moser, and Brandie Taylor exemplify the gold standard in cross-disciplinary collaboration. We greatly appreciate, and value, their generous and creative collegiality.

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References

1. Paul BD, ed. Health, culture, and community: case studies of public reactions to health programs. New York: Russell Sage Foundation, 1955.
2. Rosenfield PL. The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. Soc Sci Med 1992;35:1343–57.
3. Foster GM. World Health Organization behavioral science research: problems and prospects. Soc Sci Med 1987;24:709–17.
4. Rosenfield PL, Kessel F. Fostering interdisciplinary innovation: the way forward. In: Kessel F, Rosenfield PL, Anderson NB, eds. Expanding the boundaries of health and social science: case studies of interdisciplinary innovation. New York: Oxford University Press, 2003:378–413.
5. Judge A, Clark J. Development of trans-disciplinary conceptual aids. Union of International Associations, Brussels and Center for Interdisciplinary Creativity, Southern Connecticut State College. Available at: www.laetusinpraesens.org/docs/transveh.php.
6. Nicolescu B. The transdisciplinary evolution of the university condition for sustainable development. Available at: nicol.club.fr/ciret/bulletin/b12/b12c8.htm.
7. Nowotny H. The potential of transdisciplinarity. Available at: www.interdisciplines.org/interdisciplinarity/papers/5, n.d13.
8. Charter of Transdisciplinarity. First World Congress of Transdisciplinarity, Convento da Arrabida, Portugal, November 2–6, 1994, Article 14. Available at: nicol.club.fr/ciret/english/charten.htm.
9. Klein JT. Evaluation of interdisciplinary and transdisciplinary research: a literature review. Am J Prev Med 2008;35(2S):S116–S123.
10. Network for Transdisciplinarity in Science and Humanities. Projects 2003–2005. Available at: www.transdisciplinarity.ch/Projekte_e.html.
11. Network for Transdisciplinarity in Science and Humanities. About the transdisciplinarity-net. Available at: www.transdisciplinarity.ch/ueber_tdnet_e.html.
12. Polimeni J. Transdisciplinary research: moving forward. Int J Transdisciplinary Res 2006;1:1–3.
13. European Science Foundation. European Science Foundation Strategic Plan 2006–2010. Strasbourg: European Science Foundation. Available at: www.esf.org/fileadmin/be_user/publications/Plan20062010final.pdf.
14. Stokols DB. Toward a science of transdisciplinary action research. Am J Community Psychol 2006;38:63–77.
15. Kessel F, Rosenfield PL. Preface to new edition. In: Kessel F, Rosenfield PL, Anderson NB, eds. Interdisciplinary research: case studies from health and social science, 2nd ed. New York: Oxford University Press, 2008.
16. Albrecht G. Philosophical thoughts on a transdisciplinary model of human health. In: Higginbotham N, Albecht G, eds. Transdisciplinary thinking in health social science research: definition, rationale and procedures. Newcastle: Centre for Clinical Epidemiology and Biostatistics, University of Newcastle, 1990.
17. Trostle J. Building research capacity for health social sciences in developing countries. Soc Sci Med 1992;35:1321–1420.
18. Albrecht G, Freeman S, Higginbotham N. Complexity and human health: the case for a transdisciplinary paradigm. Cult Med Psychiatry 1998;22:55–92.
19. Higginbotham N, Albrecht G, Connor L. Health social science: a transdisciplinary and complexity perspective. Melbourne: Oxford University Press, 2001.
20. Higginbotham N, Briceno-Leon R, Johnson N, eds. Applying health social science: best practice in the developing world. London: Zed Books, 2002.
21. Ramos-Jimenez P. Asia and the Pacific: Introduction. In: Higginbotham N, Albrecht G, Connor L. Health social science: a transdisciplinary and complexity perspective. Melbourne: Oxford University Press, 2001.
22. Erinosho L. Africa: Introduction. In: Higginbotham N, Albrecht G, Connor L. Health social science: a transdisciplinary and complexity perspective. Melbourne: Oxford University Press, 2001.
23. Briceno-Leon R. Latin America: Introduction. In: Higginbotham N, Albrecht G, Connor L. Health social science: a transdisciplinary and complexity perspective. Melbourne: Oxford University Press, 2001.
24. Hadiyono JEP. The development of a transdisciplinary approach to promote the rational use of drugs: the Indonesian experience. In: Higginbotham N, Briceno-Leon R, Johnson, N, eds. Applying health social science: best practice in the developing world. London: Zed Books, 2002.
25. Johnson NA, Higginbotham N, and Briceno-Leon R. Best practice and future innovation in applying social science to advancing the health of population. In: Higginbotham N, Briceno-Leon R, Johnson, N, eds. Applying health social science: best practice in the developing world. London: Zed Books, 2002.
26. Kessel F, Rosenfield PL, Anderson NB, eds. Expanding the boundaries of health and social science: case studies of interdisciplinary innovation. New York: Oxford University Press, 2003.
27. Kessel F, Rosenfield PL, Anderson NB, eds. Interdisciplinary research: case studies from health and social science, 2nd ed. New York: Oxford University Press, 2008.
28. Olshansky SJ, Carnes BA. A journey through the interdisciplinary landscape of biodemography. Postscript 2006. In: Kessel F, Rosenfield PL, Anderson NB, eds. Interdisciplinary research: case studies from health and social science, 2nd ed. New York: Oxford University Press, 2008.
29. Ryff CD, Singer B. Thriving in the face of challenge: the integrative science of human resilience. Postscript 2006. In: Kessel F, Rosenfield PL, Anderson NB, eds. Interdisciplinary research: case studies from health and social science, 2nd ed. New York: Oxford University Press, 2008.
30. Marmot M. Social resources and health. Postscript 2006. In: Kessel F, Rosenfield PL, Anderson NB, eds. Interdisciplinary research: case studies from health and social science, 2nd ed. New York: Oxford University Press, 2008.
31. Chesney MA, Coates TJ. The evolution of HIV prevention in San Francisco: a multi-disciplinary model. Postscript 2006. In: Kessel F, Rosenfield PL, Anderson NB, eds. Interdisciplinary research: case studies from health and social science, 2nd ed. New York: Oxford University Press, 2008.
32. Cowell A. Study says older Americans less healthy than British. The New York Times. May 3, 2006.
33. Marmot M. The status syndrome: how social standing affects our health and longevity. New York: Henry Holt & Co., 2005.
34. Committee on Facilitating Interdisciplinary, National Academy of Sciences, national Academy of Engineering, IOM. Facilitating interdisciplinary research. Washington DC: The National Academies Press, 2005.
35. Stokols D, Hall KL, Taylor B, Moser RP. The science of team science: overview of the field and introduction to the supplement. Am J Prev Med 2008;35(2S):S77–S89.
36. Nash JM. Transdisciplinary training: key components and prerequisites for success. Am J Prev Med 2008;35(2S):S133–S140.
37. Berntson GG, Cacioppo JT. A contemporary perspective on multilevel analyses and social neuroscience. In: Kessel F, Rosenfield PL, Anderson NB, eds. Expanding the boundaries of health and social science: case studies of interdisciplinary innovation. New York: Oxford University Press, 2003.
38. McCulloch W. A heterarchy of values determined by the topology of nervous nets. Bull Math Biophysics 1945:7:89–93.

[m]As we further explored writings on heterarchy, we discovered an extension of the idea in the field of international relations: *Panarchy*. Emerging as a meta-frame for networking networks, the concept could be relevant to the development of team science theory and practice. As Hartzog, one of the innovators in this area, states, "The emerging complexity of our social and political structures, composed of many interacting agents, combined with the increasing importance of network forms of organization, enabled by technologies that increase connectivity, propels the world toward a transformation that culminates in a global political environment that is made up of a diversity of spheres of governance, the whole of which is called panarchy. To clarify, global linkages between individuals and groups create transnational networks consisting of shared norms and goals."[52] Here we can only note that the Marmot case study[30] might demonstrate the implementation of a productive panarchic system in the sphere of health research.

39. Crumley CL. Heterarchy and the analysis of complex societies. In: Ehrenreich RM, Crumley CL, Levy JE, Heterarchy and the analysis of complex societies. Archeological Papers of the American Anthropological Association 1995;6:3.
40. von Goldammer E, Paul J, Newbury J. Heterarchy-hierarchy: two complementary categories of description. 2003. Available at: www.vordenker.de/heterarchy/het_intro_en.htm.
41. Arbib MA. Warren McCulloch's search for the logic of the nervous system. Perspect Biol Med 2000;43:193–216.
42. Combs AL. Daddy, why are people so complex? World Futures: J Gen Evolution 2006;62:464–72.
43. Andreas S. Heterarchy and ecology: maintaining and restoring balance in living systems. Presentation at the 2004 Institute for the Advanced Studies of Health Conference, San Francisco CA.
44. White JC. Incorporating heterarchy into theory on socio-political development: the case from Southeast Asia. Archeological Papers of the American Anthropological Association 1995;6:101–23.
45. von Foerster H. Metaphysics of an experimental epistemologist. 1995. Available at: www.vordenker.de/metaphysics/metaphysics.htm.
46. Kay LE. From logical neurons to poetic embodiments of mind: Warren S. McCulloch's project in neuroscience. Science in Context 2001;14:591–614.
47. American Philosophical Society. Warren S. McCulloch Papers. Available at: www.amphilsoc.org/library/mole/m/mcculloc.htm.
48. Crumley CL. Remember how to organize: heterarchy across disciplines. In: Beekman CS, Baden WW, eds. Nonlinear models for archeology and anthropology: continuing the revolution. Hampshire UK: Ashgate Publishing, 2005.
49. Crumley CL. Historical ecology: integrated thinking at multiple temporal and spatial scales. In: Hornborg A, Crumley CL, eds. The world system and the earth system: global socioenvironmental change and sustainability since the Neolithic. Walnut Creek CA: Left Coast Press, 2007.
50. Fairtlough G. The three ways of getting things done: hierarchy, heterarchy and responsible autonomy in organizations. Devon UK: Triarchy Press, 2005.
51. Wilken T. Heterarchy: the secret of Japan, Inc. Available at: futurepositive.synearth.net/2005/05/13.
52. Hartzog P. Panarchy: Governance in the network age. Available at: www.panarchy.com.